Coquitlam/Buntzen Project Water Use Plan

Lower Coquitlam River Substrate Quality Assessment
Index

Implementation Year 5

Reference: COQMON-8

Study Period: 2010-2011

Northwest Hydraulic Consultants

April 2012
EXECUTIVE SUMMARY

The Coquitlam River substrate quality assessment was established by BC Hydro as part of the Coquitlam-Buntzen Water Use Plan (WUP) Monitoring Program to investigate the extent to which recommended channel substrate maintenance ‘flushing’ flows have been effective in improving substrate quality. As prescribed in Water Use Plan deliberations, the flushing flows are to be achieved opportunistically with annual releases of 30 to 50 m$^3$/s from the dam, for three to five days in duration, that coincide with high tributary inflows to produce total flows of 70 to 100 m$^3$/s. It is intended that these flows will reduce the quantity of sediment less than 10 mm diameter from the upper 10 to 20 cm depth of substrate, thereby increasing fish productivity by improving substrate conditions for egg incubation and juvenile rearing. The largest tributary, Or Creek, is thought to be the largest source of sediment to lower Coquitlam River (NHC, 2001) so prolonged flushing flow releases will likely be required to ensure that sediment delivered during high inflow events travels far downstream. Gravel mines along the west side of the river potentially also contribute significant quantities of fine sediment to the river, but there are insufficient suspended sediment samples and turbidity measurements to make any definitive statement.

This report presents the results of the fifth year of substrate assessment under the Coquitlam-Buntzen WUP. Surface samples are typically collected in winter (January/February), Spring (April/May) and late summer/autumn (September). Bulk subsurface samples and surface pebble counts are typically collected during summer low flows. Flows remained well below the threshold for flushing flow criteria throughout the data collection period in 2010, but there have been several large, short duration flood flows in mid-October, 2009 and in early the following January. The total fraction of fine material (< 10 mm) ranged from 0% to 40% at individual sampling sites, a bit less than was observed in 2009 but within the range of historic variability. The fine fraction had declined at PSS 15 by January, indicating that the local off-channel source was no longer contributing fine sediment and no fine sediment at all was recorded downstream at PSS 10. The highest reading was found in PSS 1 for the first time, where the material entrained from upstream appears to have accumulated. By April, 2010 the average fraction of total fines had increased to longer term conditions, but they further declined by September in most upper sections (possibly by the June dam release) and in most lower sections by early October following a high flow in late September.

In general, it is very difficult to make definitive links between flows and changes in surface grain size distribution as there are no consistent spatial and temporal trends. There appears to be a range of natural variability that occurs regardless of the occurrence of flushing flows caused by the transport and deposition of sediments by more modest floods. Results are also confounded by sampling variation as it is not possible to locate exactly the point on the bed where previous photos were collected. The lack of a clear relation has been previously demonstrated. For example, there was a general increase in sand content at most sampling sites by February 2008 despite large flows in late 2007 (that almost met flushing flow criteria). Similarly, there was no clear association between the sand fraction and flow magnitude in 2009; most sites showed a decrease, but a few sites showed an increase. These results indicate that that photo sampling program is not able to meet management objectives and it is recommended that this part of the monitor be eliminated. The bulk sampling should be continued, but only after the occurrence of a flushing flow, and at or close to previous sampling sites. It is also recommended that additional
exposed bars be sampled if additional suitable monitoring locations can be identified. Given the coarse substrate, freeze-core sampling in the wetted channel has been proven unsuccessful, and should not be revisited.
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1 INTRODUCTION

1.1 BACKGROUND

Coquitlam River flows into Fraser River about 30 km east of Vancouver, BC (Figure 1). BC Hydro and Power Authority (BC Hydro) owns and operates the Coquitlam-Buntzen Hydroelectric Project, located about 17 km upstream from the mouth of Coquitlam River. The project consists of dams on Coquitlam and Buntzen Reservoirs, a diversion tunnel from Coquitlam Reservoir to Buntzen Reservoir, and two generating stations on Indian Arm. Construction of Coquitlam Dam began in 1910 and the project was brought into service in 1914. Coquitlam Reservoir is also used by Metro Vancouver as a source of potable water for the region.

Previous studies (NHC, 2001; NHC, 2006; NHC, 2007, NHC, 2008; NHC, 2009, NHC, 2010) have documented the existing channel morphology and substrate (bed sediment) conditions in lower Coquitlam River below Coquitlam Dam. Overall, the channel has become much narrower since regulation and the coarse, formerly mobile substrate is now rarely mobilized and has become embedded with fine sediment. The altered substrate is thought to provide degraded spawning, incubation and rearing habitat for salmonids (NHC, 2001; BCH, 2005). NHC (2001) recommended a range of flushing flow releases from the Coquitlam Dam that would be required to improve or maintain channel and substrate conditions. Channel maintenance flows are large discharge events that result in channel enlargement, general bed and bar mobilization, and removal of riparian vegetation. Under the current regulated flow regime, these flows are expected to occur rarely. Substrate maintenance flows are smaller discharge events designed to remove fine sediment from the surface layer of the substrate without causing major channel changes.

In 2005, BC Hydro commenced a 12-year monitoring program of flushing-flow effectiveness under the Coquitlam-Buntzen WUP. The key question to be addressed is whether the recommended flushing flows would result in improved substrate conditions, hence increased fish productivity in lower Coquitlam River. As per the NHC (2001) recommendation the CC endorsed an opportunistic high-magnitude, short-term substrate maintenance (flushing flow) that consists of a targeted annual release of 30 to 50 m³/s for three to five days in duration that coincides with high natural inflows (mainly from Or Creek) to produce a total flow of 70 to 100 m³/s (BC Hydro 2005). The targeted annual release is based on the total release capacity of the lower level outlets and fish valves. Previous studies have indicated that flows of this magnitude are expected to remove up to 5000 m³ of sand from the near-surface substrate layer to a depth of 10 to 20 cm if they are sustained for several days (NHC, 2001). Flows of lower duration are apt to mobilize finer sediments from the bed but not to flush them from the reach. In addition, the flushing flows are thought to be effective at recruiting new gravel sources through erosion, and routing this material downstream. Monitoring since 2006 initially revealed a decrease in the amount of material in the fine fractions found on the surface following flushing (or near flushing) flow events. However, there have been no flushing flows since 2007 so it is difficult to confirm that the program is meeting objectives.
1.2 Flushings Flows

The flushing flow criteria endorsed by the consultative committee during formulation of the WUP was one of four flushing flow options presented by NHC (2001). NHC was commissioned to investigate flows required for substrate or channel maintenance with the objective of maximizing the availability of suitable fish habitat. BC Hydro provided NHC with a set of possible future operational regimes which provided a bracketing set of criteria for investigating impacts to substrate condition.

There are different types of flushing flows that can be defined based on the objective. Smaller magnitude flows are required, for example, to prevent deposition of finer material on the bed and to remove finer sediments from the surface without disturbing the coarser particles. Removing fines from the subsurface requires larger flows capable of mobilizing the coarser surface layer in order to expose the finer subsurface material. In effect, this requires a condition of general bed material transport. Since channel conditions vary along the channel, it should also be realized that the effects of a particular flow will similarly vary. It is believed that a flow sufficient to remove fine material from the subsurface in upper reaches (2b, 3 and 4) may result in the deposition of this material downstream in lower gradient reaches (1, 2a). Similarly, a flow designed to remove fines from the subsurface in lower reaches only is not likely to disturb the coarser surface layer in upstream reaches, but may remove some of the finer material from the surface layer.

The magnitude of flows required for mobilizing the bed was calculated from the Shield’s parameter for the threshold of particle motion:

\[ \theta = \frac{\rho g d S}{(\rho_s - \rho)g D} \]

Where \( \rho \) and \( \rho_s \) are the density of water and sediment, \( d \) is flow depth, \( S \) is channel slope, \( g \) is the gravitational constant and \( D \) is a representative grain size. The Shields number ranges between 0.03 and 0.06, with a value of 0.045 commonly used for gravels. By re-arranging terms, one can derive the size of material that can be moved by a particular flow (strictly, by the surrogate variable, depth). Depth is a function of discharge, and the relation between the two variables was determined through development of a Hec-Ras backwater model (NHC, 2001).

Based upon the above relation, it was estimated that a discharge of 100 to 110 m\(^3\)/s was required to just mobilize the coarse bed in reaches 2 and 3, while a more modest flow of 50 to 70 m\(^3\)/s would mobilize the bed in reach 1 (where bed sediments are finer). The duration of flow required to entrain fine sediment at these mobilizing flows was estimated from the empirical function provided by Wilcock (1998) as:

\[ T = 2.9 D^{0.5} \]

Where \( T \) is the duration of the flow in hours and \( D \) is grain size in millimetres (mm). Based on this relation, material up to 10 mm in diameter would require flows up to 100 m\(^3\)/s for roughly 9 hours minimum to entrain the material, and likely a day or longer to remove it downstream. In the previous year of assessment (2009) flows remained above threshold conditions for 6 hours.
which is enough to just mobilize materials up to 4 mm diameter (not remove them) but would likely have removed sands (< 2 mm). Hourly flow data were not available for 2010 so the analysis can not be repeated. A more thorough discussion of flushing flows will be provided in the next analytic report (2012) but this summary is provided to assist readers in interpreting the annual changes that are observed on the bed surface, even when the flushing flow criteria has not been met.

1.3 **Objectives and Approach**

The main objective of the substrate quality monitor is to evaluate whether flushing flows result in an improvement to substrate quality and fish productivity on Lower Coquitlam River. This is to be done by comparing the results of this study program with those of the Coquitlam River Fish Productivity Index study program (BC Hydro, 2005) which establish spawning and rearing success metrics for target fish species. In order to evaluate the effectiveness of the flushing flows, the following null hypotheses are to be tested:

H1: Substrate composition is not significantly affected by flushing flows that meet criteria defined during the Coquitlam-Buntzen WUP project.

H2: Fish productivity is not correlated to substrate composition as measured by surface areal fraction of fines in representative channel locations on lower Coquitlam River.

H2a: Egg-to-fry survival is not correlated to substrate composition.

H2b: Smolt production is not correlated to substrate composition.

H2c: The areal fraction of fines is not less than the bio-standard thresholds identified in relevant literature.

If H1 is refuted, then the following additional hypotheses are to be tested:

H3: There is no correlation between substrate composition and flushing flow mechanism (regulated or unregulated).

H4: There is no correlation between substrate composition and duration and/or magnitude of flushing flow.

It is understood that the adopted sampling protocols may be inadequate to properly test these hypotheses until sufficient data have been collected, so the rejection (or not) of any hypotheses should be considered preliminary and subject to change.

Biostandards for substrate composition referenced in Hypothesis H2c are quantified by the relative fraction of bed material falling within the less than 0.85 mm and 0.85 to 9.5 mm grain-size classes as specified by Tappel and Bjorn (1983). These limits are rounded off to 1 mm and 10 mm to reflect the level of measurement precision based on our sampling procedures. Two main techniques have been adopted to measure grain-size composition of the bed material. For

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1 In the program terms of reference, these are incorrectly referred to as alternative hypotheses.
the surface layer, a photogrammetric technique is used whereby the river bed is photographed and grain size (b-axis) is measured from scaled photographs using Geographic Information system (GIS) software. Surface samples are collected at 9 transects along lower Coquitlam River believed to be representative of spawning and rearing habitats (BC Hydro, 2005). Subsurface samples are collected through bulk sampling efforts at one site near the downstream limit of the study area and at a second site upstream near Gallette Avenue. The subsurface samples are far more onerous to collect, especially in coarse material and/or within the wetted channel which limits potential sampling sites on Lower Coquitlam River.

According to the monitoring program terms of reference, the subsurface samples were to be collected in order to address the uncertainty associated with using the surface analysis as a proxy for volumetric substrate quality. Since surface areal photographs are not collected during the summer, surface grain size distribution is alternatively described using manual surface pebble counts (commonly referred to as Wolman counts). The uncertainty of using surface pebble counts to describe subsurface quality was to be tested annually with the following additional null hypothesis:

H5: Substrate quality as described by surface areal photogrammetry is not significantly correlated to substrate quality as described by volumetric bulk sieve tests.

The surface and subsurface grain size distributions are related, with the surface corresponding to a truncated sample of the subsurface. The surface is generally coarser because of selective removal of sands and fine gravel during waning flood flows or during more modest discharge events.

The schedule for surface sample collection, specified by BC Hydro, was designed to coincide with the spawning, incubation and rearing phases for salmon in lower Coquitlam River, which includes the weeks of:

15 October: start of spawning;
15 January: mid-incubation; and
1 May: end of emergence.

It should be recognized that poor weather conditions, including heavy rain or snow, high water levels and elevated turbidity are amongst the uncontrollable factors that make sampling on target dates problematic. However, provided there are no very large flows between the sampling target date and the actual sampling date, the substrate morphology does not change appreciably. Subsurface samples are specified to be collected only once per year during early summer when flows are lowest.

This data report presents the methodology and results for the fifth year of the current monitor and provides a comparison to results presented in the previous year. The substrate quality results are interpreted in consideration of the annual hydrograph (recorded by Water Survey of Canada), which is typically dominated by large autumn and winter rainstorm-runoff events and flow releases from Coquitlam Dam.

The 2010 program began on January 27 and mid-incubation photo sampling was completed the following day during clear water conditions. Flows were too high to complete the sampling on the
target date. The next set of sampling was initiated on April 29 and completed the following day, just prior to the target emergence date of May 1 during favourable weather and water conditions. At PSS 13, substrate photos are now generally taken at an alternate site roughly 200 m downstream of the original section line. This change was necessary as the main channel has shifted towards the right bank and become deeper, making the original site inaccessible except during the lowest flows.

Wolman (surface) samples and bulk (subsurface) samples were collected at PSS 7 on July 13. during this site visit, the depression from a bulk excavation taken two years earlier was still clearly visible. The large mid-channel bar at PSS 2 was sampled on July 23 and as at the previous site, depressions from previous removals were still visible, so the sampling was moved from the head of the bar to the right bank bar edge where the surface material was visibly finer. Further sampling near this site will determine if this part of the bar becomes mobilized at higher flows.

A summary of the 2010 program in comparison to the targets set forth in the WUP is provided in Table 1.
2  LOWER COQUITLAM RIVER

2.1  PHYSIOGRAPHY AND SURFICIAL MATERIALS

Coquitlam River drains an area of roughly 270 km² in the southern Coast Mountains (Figure 1). The watershed can be divided into two sections above and below Coquitlam Dam. The lower watershed drains an area of 79 km² and the contemporary channel has incised through a thick sequence of sediments deposited during late Quaternary glacial advances (Armstrong, 1990). These sediments include glaciofluvial outwash sands and gravels, deltaic silts and fine sands, glaciomarine and glaciolacustrine clays and silts, and bouldery glacial till. Downstream of Gallette Avenue and extending nearly to Lougheed Highway, the river becomes less confined and flows through glacial till overlain by stony glaciomarine clays and sandy beach sediments deposited during elevated sea-levels at the time of the most recent deglaciation. Further downstream, the river flows across post-glacial alluvial fan deposits and Fraser River floodplain deposits.

Sediments in the river are largely derived from tributary inputs, mass wasting of glaciolacustrine deposits and gravel mining activities. The mountainous Or Creek (23.5 km²) enters Coquitlam River about 1.5 km downstream of the dam and is believed to be the primary contributor of sediment to the river at present (NHC, 2001). Or Creek transports a wide range of sediment grain sizes ranging to cobbles and boulders, while high eroding glaciolacustrine terrace scarps near the mouth of the creek are a significant source of silt and clay. Erosion of glaciolacustrine deposits is also observed on the west side of the river, especially during wet periods. The other main tributaries below the dam (Scott and Hoy Creeks) enter Coquitlam River downstream of PSS 1 and as a result they have no impact on flow or sediment regimes within the study area. Sediment derived from erosion of channel banks along lower Coquitlam River has been minimal since regulation.

Gravel mining activities on the west side of the river are an additional sediment source. Wastewater from the mining is treated in settling ponds then discharged into the river. Most of the sediment currently introduced to the river consists of fine sand, silt and clay, which increase turbidity below the point of discharge. Most turbidity events observed in the river that are not related to high flows are believed to be a direct consequence of mining activities. Quilty (2003) reported that turbidity levels below the mines were up to 13 times greater than measured turbidity levels upstream of the (then) GVRD gate during 2002 sample dates. There has been no consistent monitoring of turbidity and suspended sediment concentrations upstream and downstream of the gravel mining sites since 2006 and limited available data are inadequate to provide any analysis or interpretation.

2.2  CHANNEL MORPHOLOGY AND SUBSTRATE

Lower Coquitlam River exhibits an irregularly sinuous meandering morphology with occasional bars and small islands. Changes in morphology on the lower river are mainly caused by variation in flow and sediment regimes and changes in bed slope. As part of IFN (Instream Flow Needs) investigations by BC Hydro, the channel was divided into five reaches that largely reflect variations in channel morphology (refer to Figure 1). Reach 4 extends roughly 1.5 km from
Coquitlam Dam to Or Creek confluence and has a gradient of 1.8%. The morphology of Reach 4 is dominated by large, irregularly spaced lag boulders that have been deposited in the river from adjacent slopes or have been exposed by channel incision through bouldery glacial till deposits. These remnant boulders are not mobilized through normal fluvial processes. Bedload transport rates in Reach 4 would have been low even prior to regulation due to the presence of Coquitlam Lake immediately upstream which effectively eliminates the downstream supply of bed material. Cobbles and small boulders stored in low bars and planar bed sections represent the sediment that would have been transported during the largest floods prior to regulation. These ‘mobile’ sediments would have been mainly derived from lateral bank erosion.

Reach 3 also has a gradient of 1.8% and extends 1.7 km from Or Creek downstream to the upstream limit of the gravel mining area. Reach morphology is similar to reach 4, but pockets of finer sands and gravel are introduced from Or Creek and are deposited along channel margins and in the lee of large boulders. As the stored volume of this material is smaller than the volume supplied, the remainder is transported downstream. Coarser material from Or Creek accumulates near the confluence as the reduced transport capacity of Coquitlam River can not remove it. Finer, cohesive silt and clay sized sediments eroded from glaciolacustrine terrace scarps along lower Or Creek have also been observed on the coarse substrate in Reach 3 (NHC, 2006). These materials are probably removed by abrasion when sand and granules are being transported over the bed.

Reach 2 includes the gravel mining area and extends 7 km downstream almost to the Lougheed Highway. Average gradient declines to 1.1%. The sub-reach along the gravel mines is referred to as Reach 2B, while the downstream sub-reach through the urbanized area is referred to as Reach 2A. The morphology of Reach 2 is dominated by boulder bars and riffles which are separated by long pools and riffles. In general, the bars are larger and less active than in Reach 3. Formerly mobile bars are now vegetated islands and are representative of pre-regulation bedload conditions. Smaller, unvegetated cobble bars located within the narrowed post-regulation channel are representative of the contemporary bedload. Sand and granules are abundant in the interstices of pool and riffle bed material. Isolated lag boulders occur throughout the reach, with greater accumulations of sand and granules located downstream. A particularly large concentration of lag boulders occurs near the downstream end of the reach. Cohesive fine sediment has been observed to accumulate on and be removed by abrasion from the bed material, as in Reach 3. The relative contribution of sand/granule and silt/clay sediments from Or Creek versus the gravel mines is not known (but could be determined using fingerprint analysis).

Reach 1 extends approximately 0.6 km upstream and 1.2 km downstream of Lougheed Highway and roughly corresponds to the alluvial fan of the river. Gradient declines further to 0.4% and the channel is not competent to transport coarser bed material sediments further downstream. The channel is confined by dikes and has been aggrading for decades (NHC, 1976; NHC, 2001). Ongoing aggradation is evident from the accumulation of cobbles on the upstream side of young deciduous trees and plants on the bars, and finer sediment in the lee of this vegetation. The dominant substrate size class ranges from cobble at the upstream end of the reach to fine gravel at the downstream end. Gradient continues to decline (to 0.07%) in the lowermost Reach 0 which extends across the Fraser River floodplain. Reach 0 is not shown in Figure 1 as it is not included in the monitoring program.
2.3 **HYDROLOGY**

The Water Survey of Canada (WSC) operates a streamflow gauging station (08MH002) at the CP Rail Bridge, 0.4 km downstream of Lougheed Highway. The mean annual flood (based on daily discharge) in the lower Coquitlam River prior to regulation has been estimated to be 270 m³/s (NHC, 2001). Since the onset of regulation, only three floods in 1921, 1955, and 1961 have exceeded this value. All three of these floods included uncontrolled spills from Coquitlam Dam. Since 1968, the mean annual maximum daily discharge has been 72 m³/s, close to the minimum flow estimated to be required for substrate maintenance.

Coquitlam River flow conditions during the 2010 sampling program are presented in Figure 2. The data were provided directly by WSC to BC Hydro for the period October 29, 2009 to February 2, 2011. This data indicates maximum daily discharge of 136 m³/s on October 30, 2009 with a second large event of 80 m³/s roughly two weeks later (not shown in figure). Instantaneous flows would have been even larger. These values are much greater than originally provided (as presented in NHC, 2010) and would have resulted in some flushing of surface fines but do not conform to the definition of a true flushing flow. There was another large single day flow of 74 m³/s on January 14, 2010 which is before the mid-incubation sampling was completed. Flows subsequently remained low through the remainder of the monitoring period. The lowest flows under the current operating regime are expected to occur in June or July and remained less than 2 m³/s from mid- to late July.

Figure 3 compares the discharge at the Water Survey gauge to the record of daily dam releases. Total releases were roughly 40 m³/s for more than 36 hours in mid January but the additional contribution from natural inflow was not sufficient to sustain flows above 70 m³/s for more than the single day. There were also fairly large releases in late June and September but natural inflows were similarly too small to achieve flushing flow criteria. Based on maximum dam releases over the past two years, natural inflow – mainly from Or Creek – must be sustained at 30-40 m³/s for at least three days simply to create the opportunity for flow augmentation. This condition did not exist in 2010.
3 SUBSTRATE MONITORING METHODS

3.1 BACKGROUND

The surface and subsurface components of river substrate typically differ in grain-size composition and are sampled differently due to accessibility and statistical considerations (Kellerhals and Bray, 1971). The surface layer is generally coarser than the subsurface due to winnowing of fines during waning flood flows or smaller events that do not mobilize the entire bed. The reverse process can occur on regulated rivers as finer sediments accumulate on the surface due to the reduction in the magnitude and duration of peak flows. The surface sediment is thought to be representative of habitat quality for fish use (Tappel and Bjornn, 1983). Fine sediment accumulation can degrade spawning and rearing habitat by reducing the supply of oxygenated water to eggs, or by physically blocking the emergence of fry (Kondolf and Wilcock, 1996). Similarly, fine sediments also reduces invertebrate habitat.

We have adopted two established techniques for characterizing the grain size distribution of the surface. These techniques include pebble counts and photogrammetric analysis. The photogrammetric technique generally yields results that are less operator-biased than manual counts (Bunte and Abt, 2001) but bias is minimal if the sampling is done carefully. The subsurface layer represents the material that is thought to move as bedload during channel forming or maintenance flows. The approach for bulk sampling and analysis of the subsurface material is well established (Church et al., 1987). A more detailed discussion of the difference between surface and subsurface sediments, and of sampling and analysis requirements for the surface and subsurface substrate monitoring, is provided in NHC (2006).

3.2 PHOTOGRAMMETRIC SURFACE SAMPLING

Photogrammetric surface samples were collected at the 9 photo sample sites (PSS) shown in Figure 1. The surface sample sites were distributed according to spawning or rearing habitat types as specified in the WUP decision process (BC Hydro 2005). Site characteristics are presented in Appendix A and summarized in Table 2. Each photo site consists of a cross-channel transect where photos were taken at ¼, ½, and ¾ distance across the main channel (labelled L, M, and R for left, middle and right). Two or four photos were taken at each of the three points (L, M, R) across each transect, yielding a total of either 6 or 12 photos per site on each sample date. This sampling effort is designed such the truncated sample size (number of particles with a b-axis less than 64 mm) is usually greater than 100 to make the samples statistically representative of the actual surface grain size distribution (after Kellerhals and Bray, 1971).

Surface substrate photographs are taken using a 65-cm long, 36-cm diameter Plexiglass tube adapted from a design used in Alaskan stream studies (Whitman et al., 2003). The tube is painted black, fitted with a clear plexiglass bottom, and mounted on 5-cm long Plexiglass legs (photos of the device and its implementation are provided in previous NHC reports). There is a removable, black plexiglass lid with camera mount and viewing hole. This design produces a relatively lightweight sampling tube which blocks out all light except for that which filters in from the bottom. The use of a digital camera with manual settings and polarizing filter allows photographs to be sampled in various light conditions and consistently produces sharp, high-
resolution images. The height of the sampling tube allows for substrate to be photographed in clear water up to 1 m deep provided velocities are low. The sampling tube can be used in moderately turbid conditions provided the water is reasonably shallow. In shallow turbid water, the clear plexiglass base can be placed close to the substrate surface, minimizing the depth of water column through which the photo is taken. Photo sampling can not be completed in deeper, turbid waters.

The b-axis dimension of the particle underlying each grid node is measured directly from the digital photographs on-screen using GIS software. A metal bar of known dimensions that rests on the bed in each photo is used to scale each image. A 64 mm x 64 mm ‘digital’ sampling grid is created in the GIS and superimposed on each image. The 64 mm size is analogous to the division between gravels and cobbles, and was chosen as a truncation limit for the grain size analysis. Dimensions of each sampled particle are measured to the nearest tenth-millimetre and recorded into a database. The actual number of samples obtained in each photo depends on the bed material texture (i.e. the number of grid nodes occupied by grains greater than 64 mm in size), which varies considerably between sites.

3.3 Bulk Subsurface Sampling

Bulk samples of subsurface material were collected on a small mid channel bar near PSS 7 on July 13 and on a large mid-channel bar near PSS 2 on July 23. The site near PSS 7 was first sampled in 2007, and was chosen to represent bed conditions typical of upstream spawning and rearing conditions. A previous excavation pits was still largely visible, providing evidence that there has been little or no bed disturbance and low sediment transport since at least 2009. This is consistent with the lack of sustained flushing flows. PSS 2 was initially sampled in 2000, with subsequent samples in 2003 and in each year since 2006. As at PSS 7, excavation pits from previous years were still partly visible so the sampling location was moved from the head of the bar to the left bar edge where there was no past disturbance.

For the subsurface sampling, the surface layer of substrate is cleared away and the underlying subsurface material excavated and weighed. The mass of the bulk-sieve sample required to represent the subsurface depends upon the size of the largest particle in the sample (Church et al., 1987). Typically, the 1% criterion is applied where the largest clast in the sample should not represent more than 1% of the sample mass. At PSS 2, the bulk mass sampled was 243 kg (have the volume sampled and sieved in 2009) reflecting finer sediments on the bar edge. For comparison, 351 kg of material was sampled at PSS 7 upstream. The subsurface bulk samples were manually excavated and sieved on-site. Fractions passing through standard-sized, square-mesh sieves were recorded and material passing through the 25-mm mesh size was collected, dried and sieved at ½ φ intervals. The results of both sets of analysis are pooled together and the fraction finer-than (by mass) is plotted in (see Figure 12 and Figure 13).

Manual pebble counts were also collected at both sites to compare surface and subsurface composition, and to examine the trends of each over time. This procedure is commonly referred to as Wolman Sampling, and is fundamentally similar to the photogrammetric sampling (as the b-axis may be inclined or hidden on some photos, the distributions may differ but should be correlated). For the surface sampling, a tape was laid on the bar surface and the grains underlying the tape at specified intervals were collected. A total of 150 grains were selected at
PSS 2 and 141 grains were selected at PSS 7, both along 2 parallel transects. The b-axis of each grain was measured manually using a ruler. Where the surface was dominantly sandy, grain size was recorded as 1 mm.

### 3.4 Impacts to Salmonids

In order to address hypotheses relating fish productivity to the substrate sampling results, changes in the surface and subsurface grain size distributions over time are compared to one or more fish population metrics. In the 2009 NHC analytic report, it was suggested that the most appropriate fish metric is egg-to-smolt survival. Egg-to-fry survival habitat conditions are affected by changes in substrate conditions as measured during late summer (spawning) winter (incubation) and spring (emergence) sampling. Previous analyses have demonstrated that survival rates for pink and chum salmon appear higher when substrate surface fines are reduced. No similar link has yet been established for coho or steelhead salmon because of insufficient data. Bjornn and Reiser (1991) add that emergence can be a problem if interstitial spaces are not large enough to allow alevins to pass through the substrate. Difficulty with emergence was found to occur when the percentage of fine sediments (< 6.4 mm) exceeded 30 - 40% by volume. Results of the bulk sampling analysis (see Figures 12-13) suggest that alevins may be facing difficulty in emerging from the bed, but only two bulk sampling sites are not adequate for describing conditions throughout the reach where spawning occurs.

Since flushing or near-flushing flows are expected to reduce surface fines, a tentative correlation was made between flushing flows and increased fish productivity. The sediment data since collected (during 2009 and 2010) will be used to provide further evidence that this link is established (or not), but relating surface sediment quality to fish productivity is not the focus of this data report. In any case, egg-to-smolt survival rates for 2009 and 2010 are not yet available. Future analyses may also include additional metrics of fish productivity, and it is recommended that benthic data also be related to substrate results. Benthic invertebrates are not mobile (compared to salmon) and are likely to be strongly affected by changes in substrate quality. However, the lack of flushing flows since 2007 may complicate the establishment of any definitive trends.
4 SUBSTRATE MONITORING RESULTS

4.1 PHOTOMGRAMMETRIC SURFACE SAMPLES

The fraction of measured grains is summarized for the two main indicative size ranges – less than 10 mm and 10 mm to 64 mm. The less than 10 mm range is further divided into two categories corresponding to less than 1 mm (sand) and 1 mm to 10 mm (fine to medium gravel). The data collected and analyzed in 2010 are summarized in Table 3 (truncated to 64 mm) and trends for 2010 are illustrated in Figures 4 to 6. The truncated results show that the target threshold of 100 was not achieved at 4 sites in January, 6 sites in April, and 5 sites in September. This is an increase over the previous three years despite the same sampling effort (the sampling effort was increased after 2006 to reduce this problem). It is not immediately obvious that this is due to an actual change on the bed, or simply reflects sampling variability. Almost all of the truncated samples are still greater in count than 50, however, which is the minimum recommended for analysis (Kellerhals and Bray, 1971). In general, the results show that the bed is dominated by the 10-64 mm fraction, with medium sands typically occupying only a very small fraction of the bed surface. However, because sands can be introduced and transported during flows well below the flushing flow threshold, the sand fraction can be high at some sections (e.g. PSS 1 during January). Since sand deposits have been found to be very transient, a high sand fraction does not persist at any location measured. The sampling interval (~ 4-5 months) is too coarse to estimate the longevity of the transient sand deposits.

At all sites sampled in 2010, the total fraction of fine sediment < 10 mm ranged from 0% to 40%, somewhat less than the range measured in 2009, but similar to previous years (Table 4). The total fine fraction is less sensitive to operator / sampling bias than the subdivision into 2 separate categories, and is thought to be a good overall indicator of substrate quality. Figure 6 shows that the total fine fraction generally increased between January and late April, but had declined by the next sampling period in September. There is no clear spatial trend in the distribution of the fine to medium gravel along the channel, following the results of the previous year of monitor. The highest values in 2010 were found within the gravel mining reaches, and in PSS at the downstream end of the study area. This fraction used to be high at PSS 15 but a local sediment source does not presently contribute fines. Overall, the lack of any clear pattern is an indication that the supply of fine sediments found on the surface is not strongly correlated to the flow regime, rather it partially depends on the supply from hillslopes and tributary streams. This suggests that this material is transient (especially the coarse sands). Consequently, even small differences in sampling location may produce large differences in the fine fraction at the same transect over time if pulses of fine sediment are moving through.

The average of the total fine fraction at all sections over time is also provided in Table 4. This ‘river mean’ is presented as a method of integrating results at all sections for each date. However, a mean value a biased indicator of substrate quality for the entire channel since each sampling section represents a different length of channel. The representative length of each section corresponds to the sum of distances mid-way to up and downstream sampling locations, or to study bounds (for PSS 1 and PSS 15). Dividing these lengths by the total study length gives the proportional length fraction, which is multiplied by the fine sediment fraction for each sampling section to determine the weighted mean. The weighted average ranged between 15% and 24% in 2010. The values for January and September are the lowest that have been recorded.
since 2006 but the April result was similar to previous years results. Given the lack of significant flow events between January and September sampling, it is likely that these results represent sampling variability.

At the sites sampled in January 2010, the fraction of material less than 1 mm was less than 1% at all locations except PSS 1 (33% - Table 4). Six sites had no measureable material < 1 mm. The overall result is quite similar to that observed in 2009. By April, there were small increases at most sites, but the fraction at PSS 1 was greatly reduced to 4%, while by September, there were small decreases at most sites. The changes are small enough to represent sampling variability except at PSS 1. The weighted mean for sand reveals that the representative sand fraction did not exceed 3% in 2010, which is lower than in previous years extending back to 2006 and is below the threshold considered harmful for incubation (Kondolf, 2000). The change in the distribution of the sand fraction over time for the different sampling sites is given in Table 5 and results are plotted in Figure 5. Previous analysis has shown that flushing flows do not appear to be clearly related to the surface composition of sands since much more modest flows are able to transport sands.

The size fraction in the 1 to 10 mm size class ranged from 0% to 26% in January, 2010. A value of zero in this size class has only been recorded once previous (at PSS 13 in 2008). The 26% fraction at PSS 9 is amongst the highest recorded at any site since June 2006 (Table 6), but was even greater the previous year, suggesting a possible local input. However, this fraction continued to decline through to September (Figure 6). Overall, the fraction of material in this size class in April was high relative to most previous reporting periods but was within the range of with 28% recorded at both PSS 7 and 8. Readings were actually relatively high at all sites downstream of reach 3, resulting in the highest (22%) weighted mean yet recorded, though values were nearly as large in June 2006 and May 2008. The high values in the spring emergence period could affect egg-to-smolt survival rates and the abundance of benthics. With the exception of the high spring readings, the weighted mean fraction has been fairly stable since 2007.

The fraction of material in each size class does not appear to show any consistent downstream trend over time. Figures 7-9 show all historic measurements at each sampling location. Overall, the plots appear almost chaotic, with the measured fraction at each section both increasing and decreasing over time, and no obvious link between changes at upstream reaches (PSS 7-15) with changes at downstream reaches (PSS 1-3). The only exception is an apparent reduction in the 1-10 mm fraction to February 2008 following a series of flushing flows, but the effect was temporary. The weighted means reduce this variability, but similarly show no clear spatial or temporal pattern. The results are confounded by several factors, such as the high degree of sediment sorting at PSS 1 and PSS 2 relative to upstream sections, large boulders upstream that provide protected sites for fine sediment accumulation, and periodic pulses of sediment from tributaries. Adding to the confusion is the lack of flushing flows since late 2007, but the passage of numerous near-flushing flow events and high magnitude, short duration flows capable of initiating partial bed transport, especially for sands and fine gravels. Given these findings, it appears that it might not be possible to relate surface substrate changes to fish productivity indices.
4.2 **Surf ace Pebble Counts**

The manual surface samples collected on the gravel bars in 2010 contained fine-sediment fractions (less than 10 mm diameter) of 7% at PSS 2 (Table 7; Figure 10) and 9% at PSS 7 (Table 7; Figure 11). The breakdown between the fraction finer and coarser than 1 mm is not measured for surface counts. The PSS 2 result shows a small decrease in surface fines relative to 2009, but is within the range of previous measurements, and less than shown for most previous samples (as high as 19% in 2000). The PSS 7 result is bracketed by the previous results. All 2010 samples were collected in the same location as in the previous 3 years so results appear likely to reflect real (modest) changes in surface substrate composition. However, some sampling variability is also expected. For comparison, the median grain size at PSS 2 coarsened from 36 mm in 2000 to 50 mm in 2006 and has since become finer, back to 36 mm. There has been no change in the surface grain size distribution since 2009. In general, these changes likely reflect the addition of finer sediments from smaller flow events (though there was no similar small change by 2010). Since these events can also winnow finer sediments (coarsening the bed), the somewhat inconsistent nature of surface fining or coarsening makes it difficult to definitively establish causal efficacy. There has been no change in the median grain size at PSS 2 since 2007, consistent with the lack of flushing flows, and the requirement that these be larger than at PSS 2.

For larger particles, the distributions at PSS 2 are very similar since 2008 and virtually identical for particles with a mean diameter greater than 70 mm. Given that there have been no flows capable of moving these larger clasts, the observation is expected. For all sizes less than 70 mm, however, the 2009 and 2010 distributions are finer, close to that measured in 2007. The 2009 distribution is finer because the sampling picked up a much larger fraction of smaller clasts (for example, 30% of all material smaller than 20 mm in 2009 and 2010, versus only 10% in 2008). Although the change in the finer fractions may be real, at least part of the difference is size distribution over time is caused by sampling variability. At PSS 7, the distributions are nearly identical for particles with a mean diameter greater than 30 mm. Between 2008 and 2010, the distributions are nearly identical for particles greater than ~13 mm. This is further consistent with the field observation that previous excavation pits for bulk sampling were still visible.

Previous comparisons of the photogrammetric and manual pebble-count methods of substrate surface sampling indicated that the two techniques provide similar grain size distributions overall. Some difference in the two distributions is expected because the sampling locations differ, and bar surfaces are not homogenous. There are also biases in the two techniques. Most commonly, pebble counts underestimate the frequency of finer material (though this can be avoided with careful sampling). In addition, photogrammetric distributions may be biased (underestimated) where the true b-axis width can not be measured because of hiding or particle tilting. Pebble counts have been used as a surrogate for photogrammetric sampling in the past on Lower Coquitlam River.

The real purpose of the pebble counts, however, was to demonstrate the uncertainty of using surface areal grain size analysis as an indicator of subsurface substrate quality (hypothesis H5). Although the surface and subsurface distributions are not the same, they are related in a natural (un-regulated) channel as the surface is a truncated version of the subsurface. However, on lower Coquitlam River, the surface sediments are affected by sediment supply and transport conditions while the subsurface is rarely mobilized because of the regulated flow regime.
Therefore, H5 should be rejected. However, the bulk sampling program should be maintained since it can be used to examine the potential effectiveness of flushing flows (after they occur) for the critical subsurface habitat that would not otherwise be shown. Results of the 2010 subsurface sampling are provided below.

### 4.3 Bulk Subsurface Samples

The 2010 subsurface sampling results at PSS 2 are provided in Figure 12. The results indicate a significantly finer subsurface compared to previous years which is attributed to the change in sampling location. Although this invalidates any direct comparison to previous samples, it is known that no change would have been detected if the 2010 sampling was done in the original location. The lack of flushing flows and preservation of previous sampling pits confirms this supposition. In the absence of future flushing flows, there is little point in repeating the bulk samples, but following one, both sites could be re-sampled to provide a range of particle size that are mobilized to help refine the flushing flow criteria.

With the change in sampling location there has also been a small change in the size of the largest stones at PSS 2. In 2010, none of the sampled mass was greater than 128 mm diameter, compared to 3% in 2009 and 4% in 2008. The largest clasts would only be mobilized during exceptional flow events that are rare following regulation (see Section 2.3). Replicate bulk sampling over time is a robust means of comparing subsurface grain size distributions, so the coarsening of finer (<22 mm) material following flushing flows in 2007 (which would have mobilized some of the surface), but no change to 2009, appears to be a real response, and provides support that flushing flows (or near flushing flows) reduce the amount of fines in the substrate.

The bed also became coarser at PSS 7 between 2007 and 2008 for material < 32 mm diameter. The 2010 results appear to show a general fining of the bed for all fractions smaller than 45 mm but this is not believed to be a real (or significant) change. Given that there have been no flushing flows were recorded, and the sampling pit from 2008 was still clearly visible, the difference is attributed to a change in sampling location on the small bar. The bar head should be resampled after the next flushing flow.
5 CONCLUSIONS AND RECOMMENDATIONS

Future water use decisions on lower Coquitlam River require prior knowledge that recommended flushing flows result (or do not result) in an improvement to substrate quality and fish productivity. In order to evaluate the effectiveness of flushing flows, the following null hypotheses are to be tested:

H1: Substrate composition is not significantly affected by flushing flows that meet criteria defined during the Coquitlam-Buntzen WUP project.

H2: Fish productivity is not correlated to substrate composition as measured by surface areal fraction of fines in representative channel locations on lower Coquitlam River.

A field sampling program to measure substrate quality during spawning, incubation and emergence periods for salmonids was designed with the intention of providing the basis for relating changes in substrate conditions to various fish productivity metrics. Photogrammetric surface samples were collected in January, April and September 2010 to document the fraction of surface material falling within the less than 10 mm, less than 1 mm and 1 to 10 mm size classes. There were no flows sufficient in duration to flush sediment during 2010 and none since 2007. The 2010 measurements reveal a modest increase in the total fine fraction to April with a subsequent decline by September, though there is no clear link to flows driving this change. Further, when the fraction of each class is directly compared between reaches, there is no clear pattern or downstream trend. A weighted average (based on the length of river each sampling site represents) shows no change in the total fine fraction since 2008, which appears consistent with the lack of larger flows over this same period.

The fraction of material less than 1 mm is generally much lower than the fraction in the 1 to 10 mm class, although the sand fraction can change dramatically over a single reporting period. There was only a very small fraction of medium sand (<1 mm) at all sites sampled in 2010 (except for PSS 1) so removing this material from the calculations has little effect on trends for the 1-10 mm class. Although there was a large reduction in the weighted average for this material following a near flushing flow in late 2007, this impact was nullified by the following May, and has since remained near long term average values. When plotted together, the surface sampling results for each size class since 2006 show no clear spatial or temporal trends. The values fluctuate within a range of variability that is not obviously related to the presence or absence of flushing flows. Rather, there appears to be a natural variation as finer material is mobilized and transported by flows smaller than the flushing flow threshold, while there is also natural variability caused by even minor changes in sampling location. This variability eliminates the potential to correlate surface and subsurface grain size distributions. The lack of any clear trends or patterns is an indication that the photo sampling program is not meeting program objectives and it is not possible to support or refute the underlying study hypotheses. As a result, the current photo monitoring program should be modified. Photos should alternatively be taken once annually\(^2\) as this provides an opportunity see if areal fine fractions in the future deviate from past results.

\(^2\) This strategy was further endorsed by the Coquitlam Monitoring Advisory Committee to maintain a photographic record of the bed surface.
Given the lack of large flows since 2007, the subsurface would not have been expected to change. The bulk sampling results revealed a nearly identical grain size distribution is both 2008 and 2009, confirming the absence of disturbance. At PSS 2 and PSS 7, the subsurface appears to have become finer since 2008 even though the surface has not been disturbed. At both sites previous sampling pits were still preserved, confirming the bar has remained stable. The observed fining is attributed to a change in sampling location, which is necessary to avoid previously disturbed sampling locations. It therefore appears easy to confound changes in the subsurface grain size distribution caused by flushing flows with natural variability. In the absence of future flushing flows, the sampled bars will not have been disturbed and additional sampling will not reveal any useful data.

It has been previously found that the total amount of fines in the substrate became finer following the passage of flushing flows. Since 2006, there have been 2 flows that have met the flushing flow criteria and 2 separate dam-release augmented flows that were close to this threshold. In each case, the amount of fine sediment on the surface was found to have decreased, indicating that the flushing flow experiments appear to have been successful. However, these changes were temporary and within the range of natural variability that occurs even in the absence of flushing flows. Furthermore, the surface and subsurface have not become increasingly finer in the absence of these flows. These findings further confound any efforts to resolve the management questions or evaluate the effectiveness of flushing flows for reducing fine sediments and improving salmonid habitat.

In the absence of flushing flows, the present study is not meeting its management objectives and should be revised. The photo sampling appears to be capturing a range of variability in surface grain sizes that fluctuates over time even in the absence of flushing flows. This is the combination of actual changes and sampling variability that can not be definitively linked to the flow regime. Bulk sampling is generally a robust technique for demonstrating subsurface changes, but there are few suitable sampling sites on lower Coquitlam River. At both sites sampled, there was a consistent reduction in the fine sediment fraction following an intermediate flushing flow in 2007 (when discharge exceeded the 70 m$^3$/s threshold for 3 consecutive days in March). In the absence of a new flushing flow, there is no value in repeating the bulk samples as it is known that the subsurface will not have been disturbed. Following a flushing flow, sampling should occur during low flows in the same location as previous samples were collected, if possible. Collecting samples in a new location confounds any interpretation since it can capture the variability in subsurface grain sizes that exists on a bar. It is also recommended that the program be expanded to include a third bar near Frisky Road that is comprised of mobile gravel sized material. This bar is accessible during low flows and the additional data should improve the analytical power of the study.
6  REFERENCES


TABLES
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<th>WUP Date</th>
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<td>LOCATION</td>
<td>PHOTO POINT - DISTANCE (m) FROM LEFT BANK PIN</td>
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1. Glides and runs are types of riffles; this classification is favoured by biologists. Riffles are most commonly associated with pools, especially opposite bars. Shallow reaches with emergent cobbles and boulders are also called rapids in the morphologic literature.
### TABLE 3: Photogrammetric surface sampling results for all size fractions

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<td>1</td>
<td>1</td>
<td>16%  9%  15%  36% 11%  17%  31%  35%  16%  40%  26%  34%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>24%  20%  21%  22% 19%  25%  19%  21%  20%  17%  24%  17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted Average</td>
<td></td>
<td>25%  20%  21%  21% 24%  24%  19%  20%  19%  15%  24%  16%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**TABLE 5: Photogrammetric surface sampling results for D≤1 mm**

<table>
<thead>
<tr>
<th>REACH</th>
<th>SITE (PSS)</th>
<th>FRACTION OF SAMPLED GRAINS WITH DIAMETER D≤1 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jun-06</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>0%</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>0%</td>
</tr>
<tr>
<td>2B</td>
<td>10</td>
<td>5%</td>
</tr>
<tr>
<td>2B</td>
<td>9</td>
<td>0%</td>
</tr>
<tr>
<td>2B</td>
<td>8</td>
<td>8%</td>
</tr>
<tr>
<td>2B</td>
<td>7</td>
<td>6%</td>
</tr>
<tr>
<td>2A</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>Weighted Average</td>
<td></td>
<td>3%</td>
</tr>
<tr>
<td>REACH</td>
<td>SITE (PSS)</td>
<td>FRACTION OF SAMPLED GRAINS WITH DIAMETER 1&lt;D≤10 mm</td>
</tr>
<tr>
<td>-------</td>
<td>-----------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2006</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jun-06</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>9%</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>15%</td>
</tr>
<tr>
<td>2B</td>
<td>10</td>
<td>22%</td>
</tr>
<tr>
<td>2B</td>
<td>9</td>
<td>15%</td>
</tr>
<tr>
<td>2B</td>
<td>8</td>
<td>28%</td>
</tr>
<tr>
<td>2B</td>
<td>7</td>
<td>33%</td>
</tr>
<tr>
<td>2A</td>
<td>3</td>
<td>28%</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>24%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>16%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>21%</td>
</tr>
<tr>
<td>Weighted Average</td>
<td></td>
<td>21%</td>
</tr>
</tbody>
</table>
TABLE 7: Summary of manual surface samples

<table>
<thead>
<tr>
<th>SITE (PSS)</th>
<th>Fraction of sampled grains in size range</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D ≤10 mm</td>
<td>2000</td>
<td>2003</td>
<td>2006</td>
<td>2007</td>
<td>2008</td>
<td>2009</td>
</tr>
<tr>
<td>1</td>
<td>11%</td>
<td>10%</td>
<td>10%</td>
<td>12%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>19%</td>
<td>17%</td>
<td>5%</td>
<td>15%</td>
<td>4%</td>
<td>10%</td>
<td>7%</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14%</td>
<td>2%</td>
<td>-</td>
<td>9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SITE (PSS)</th>
<th>Fraction of sampled grains in size range</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D &gt; 10 mm</td>
<td>2000</td>
<td>2003</td>
<td>2006</td>
<td>2007</td>
<td>2008</td>
<td>2009</td>
</tr>
<tr>
<td>1</td>
<td>89%</td>
<td>90%</td>
<td>90%</td>
<td>88%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>81%</td>
<td>83%</td>
<td>95%</td>
<td>85%</td>
<td>96%</td>
<td>90%</td>
<td>93%</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>86%</td>
<td>98%</td>
<td>-</td>
<td>91%</td>
</tr>
</tbody>
</table>
NOTES:
PSS #2 AND #7 - ADDITIONAL BULK-SIEVE SAMPLES (BAR) AND PEBBLE COUNTS
FIGURE 2: Annual daily discharge with 2010 target dates

- WUP target
- NHC effort
- Mean daily discharge

Date
- 1/1/2010
- 1/16/2010
- 1/31/2010
- 2/15/2010
- 3/2/2010
- 3/17/2010
- 4/1/2010
- 4/16/2010
- 5/1/2010
- 5/16/2010
- 5/31/2010
- 6/15/2010
- 6/30/2010
- 7/15/2010
- 7/30/2010
- 8/14/2010
- 8/29/2010
- 9/13/2010
- 9/28/2010
- 10/13/2010
- 10/28/2010
- 11/12/2010
- 11/27/2010
- 12/12/2010

Discharge (m³/s)
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
FIGURE 3: Hourly Coquitlam River dam releases and Daily Discharge for 2010

- **Daily discharge**
- **Dam release**
FIGURE 4: Photogrammetric surface sampling results D≤10 Coquitlam River, PSS 1-15 (Jan 2010 - Sep 2010)
FIGURE 5: Photogrammetric surface sampling results $D \leq 1$
Coquitlam River, PSS 1-15 (Jan 10 - Sep 10)
FIGURE 6: Photogrammetric surface sampling results \(1 < D \leq 10\) Coquitlam River, PSS 1-15 (Jan 2010- Sep 2010)
FIGURE 7: Photogrammetric surface sampling results D≤1
Coquitlam River, PSS 1-15 (Jun 2006 - Sep 2010)

![Graph showing photogrammetric surface sampling results D≤1 for Coquitlam River, PSS 1-15 from June 2006 to September 2010. The graph plots the fraction of samples in different size ranges over time, with distinct lines representing each size range from PSS 1 to PSS 15.]
FIGURE 8: Photogrammetric surface sampling results D≤10
Coquitlam River, PSS 1-15 (Jun 2006 - Sep 2010)
FIGURE 9: Photogrammetric surface sampling results $1<D\leq10$
Coquitlam River, PSS 1-15 (Jun 2006 - Sep 2010)
FIGURE 12: Bulk sieve subsurface grain size distributions
Coquitlam River - PSS2

GRAIN SIZE (mm)

FRACTION FINER (%)
FIGURE 13: Bulk sieve subsurface grain size distributions
Coquitlam River - PSS7

GRAIN SIZE (mm)

FRACTION FINER (%)